

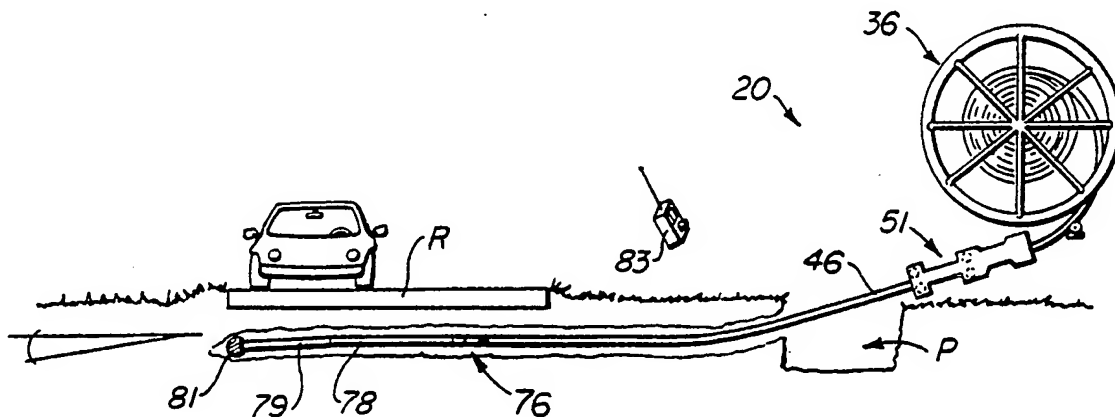
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 (71)(72) Applicant and Inventor: **JOHNSON, Howard, E. [US/US]; 3765 Bozeman Lake Road, Kennesaw, GA 30144 (US).**
 (72) Inventor: **GILCHRIST, Gregory, R. ; 1203 Gordon Combs Road, Kennesaw, GA 30144 (US).**
 (74) Agent: **GARDNER, Arthur, A.; Hurt, Richardson, Garner, Todd & Cadenhead, 999 Peachtree Street, NE, Suite 1400, Atlanta, GA 30309-3999 (US).**

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(54) Title: **UTILITY TUNNELING METHOD AND APPARATUS**

(57) Abstract

An apparatus (20) for forming an underground tunnel for the reception of cable, conduits and the like comprises a semi-rigid advancing conduit (46), and advancing and retracting mechanism (51) for moving the advancing conduit and a take-up reel (36) for receiving the advancing conduit. A hydraulic drill motor (78) is mounted to the leading end (76) of the advancing conduit by means of a coupling member (77). A bent housing (79) is mounted at a small angle relative to the drill motor for rotatably supporting a drill bit (81). The coupling (77) allows the orientation of the drill bit (81) to be changed relative to a longitudinal axis of the advancing conduit (46), allowing the apparatus to be steered effectively.

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UTILITY TUNNELING METHOD AND APPARATUSTECHNICAL FIELD

The present invention generally relates to tunneling and boring underground, and more particularly relates to a method and apparatus for tunneling and boring underground for the installation of utility cables, conduits and the like.

BACKGROUND OF THE INVENTION

The traditional method of installing utility cables and conduits includes digging a trench, laying the conduit or cable in the trench and backfilling the trench with soil. However, in some circumstances this technique can be impractical or highly undesirable. For example, where utility cable or conduit is to be installed beneath a busy roadway, the above technique disrupts traffic flow because of the necessary interruption in the road surface by the trench. There are also a number of other similar situations in which it is desirable to install utility cable or conduit without disturbing the upper surface of the ground.

Various methods and apparatus are shown in the prior art for installing underground utility cables and conduits without disrupting the upper surface of the ground. For example, U.S. Patent 4,026,371 to Takada et al discloses a system for laying small diameter pipes in which a casing is fitted with a pilot head and is hydraulically forced through the ground to create a tunnel. The pilot head includes a clinometer target and a clinometer is used for detecting the position and orientation of the head and the head is pivotally mounted so that the direction of the casing can be altered. As the clinometer requires an unobstructed line of sight with the target, the amount of alteration of direction possible with this arrangement is generally limited to the diameter of the passageway.

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One of the problems typically encountered when tunneling underground for the installation of utility cables and conduits is ensuring that the tunnel is formed along a particular desired path. U.S. Patent No. 5 4,856,600 to Baker et al. addresses this problem and discloses a drilling system utilizing a cutting head having water nozzles, with the cutting head being mounted at the leading end of a thrust conduit. The thrust conduit is pushed through the soil with a constant thrust 10 force and as it is pushed through the soil, the nozzle head rotates in a modulated manner to spend more time directing water spray at soil in a given direction to effect a movement of the leading end in that direction. While a water cutting technique such as that taught by 15 Baker et al. may have a certain applicability in providing a steering capability, it generally fails to progress quickly through hard clays or rock.

Accordingly, it is seen that a need yet remains for a utility tunneling system which can be readily 20 steered and yet which can quickly advance through the soil, including heavy clays and rock. It is to the satisfaction of such need therefore that the present invention is primarily directed.

SUMMARY OF THE INVENTION

25 In a preferred form, the present invention comprises an apparatus for forming an underground tunnel for the reception of cable, conduits and the like without digging a continuous trench. The apparatus includes an elongated, substantially continuous conduit having a 30 leading end and a longitudinal axis. A drill motor is mounted to the leading end of the continuous conduit and a drill bit is coupled to the drill motor, with the drill bit being coupled at a small angle relative to the longitudinal axis of the conduit. The drill bit 35 furthermore is oriented relative to the conduit to define

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a first drilling direction. The apparatus also includes means for changing the orientation of the drill bit relative to the longitudinal axis to define a second drilling direction and means for powering the drill motor 5 to cause rotation of the drill bit. Further means are provided for advancing the conduit along the tunnel.

Preferably, the means for changing the orientation of the drill bit relative to the longitudinal axis comprises a coupling member which allows the drill 10 bit to be rotated about the longitudinal axis while maintaining the small angle between the drill bit and the longitudinal axis.

With this construction, it is possible to utilize a drill bit which is capable of high production rates 15 (i.e. is capable of cutting through relatively hard material quickly) while also providing an effective steering capability for changing tunnel direction.

Other features and advantages of the present invention will be made clear upon reading the following 20 specification in conjunction with the accompanying drawing figures.

BRIEF DESCRIPTION OF THE DRAWING FIGURES

Fig. 1 is a perspective illustration of a tunneling apparatus in a preferred form according to the 25 present invention.

Fig. 2 is a perspective illustration of a portion of the tunneling apparatus of Fig. 1, with some elements partially removed for clarity of illustration.

Fig. 3A is a schematic illustration of a portion 30 of the tunneling apparatus of Fig. 1, showing the apparatus being used to tunnel under a roadway.

Fig. 3B is a schematic illustration of a portion of the tunnelling apparatus of Fig. 3A.

Fig. 4 is a partially cut away perspective 35 illustration of a portion of the tunneling apparatus of Fig. 1.

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Fig. 5 is a partially cut away side view of a portion of the tunneling apparatus of Fig. 1.

Figs. 6A and 6B are perspective illustrations showing two forms of a portion of the tunneling apparatus 5 of Fig. 1.

DETAILED DESCRIPTION

Referring now in detail to the figures, in which like reference numerals represent like parts through the several views, Fig. 1 shows a tunneling apparatus 20 according to the present invention in a preferred form. Tunneling apparatus 20 includes a movable support frame indicated generally at 21, including a forward tongue 22, as for towing. Four road wheels 23 are rotatably mounted to unshown axles, which axles are in turn mounted to the 15 support frame 21 for movably supporting the support frame upon the ground. The wheels 23 are covered by fenders 24.

The support frame 21 includes a rear cross member 26. Four leveling jacks or outriggers 27 are mounted to the rear cross member and to a forward portion of the 20 support frame for leveling and stabilizing the tunneling apparatus 20 upon the ground. The leveling jacks 27 are hydraulically powered and each carries a swiveling, ground engaging pad 28 at its lower end.

An engine 31 is mounted on the support frame 21 25 and powers a hydraulic pump 32. The engine 31 and the hydraulic pump 32 are substantially contained within an engine housing 33 to protect the engine and pump from the weather and to prevent operators from accidentally contacting the engine. The engine 31, the hydraulic pump 30 32 and the engine housing 33 are positioned at a forward end of the apparatus 20, as shown.

A large fluid reservoir 34 is positioned upon the support frame 21 closely behind the engine 31 and the engine housing 33. A large take-up reel 36 is positioned 35 behind the fluid reservoir 34. The take-up reel 36 is

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rotatably mounted to a pair of triangular frame members 37 and 38 which are in turn coupled to the support frame 21. The take-up reel 36 is made up of a pair of substantially identical spoked wheel members 41 and 42 sharing a common 5 hub. For example, spoked wheel 41 includes a wheel rim 43 and a series of spokes 44 extending between the hub and the rim 43.

The take-up reel 36 is adapted to receive a length of semi-rigid steel advancing conduit or pipe 46. 10 The advancing conduit 46 is rigid enough to be pushed through the ground with a minimum of deflection and yet is flexible enough to be wound upon the take-up reel 36. One end 47 of the advancing conduit 46 is in fluid communication with a hollow portion of the hub of the 15 take-up reel 36 by means of a flexible conduit 48. With this construction, fluid pressure may be communicated through the hub and correspondingly through the advancing conduit 46.

An advancing and retracting mechanism 51 is 20 mounted to the rear cross member 26 for advancing and retracting the advancing pipe 46. As best illustrated in Fig. 2, the advancing and retracting mechanism 51 includes a pair of substantially identical plates 52 and 53 mounted parallel to each other. Each plate is roughly shaped in 25 the form of a guitar and includes a big end portion indicated generally at 56, a neck portion indicated generally at 57 and a head portion indicated generally at 58. The advancing and retracting mechanism 51 is pivotally mounted to the cross member 26 at the big end portion 56 30 and the head portion 58 is coupled to the cross member by a hydraulic jack 59. A pair of upper and lower tracks 61 and 62 are mounted between the parallel plates 52 and 53 in the vicinity of the big end portion 56. Each track is made up of a number of individual gripper members to form 35 a continuous chain. Each individual gripper member

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includes a concave surface for engaging the outside surface of the advancing conduit 46. Upper track 61 is driven by unshown hydraulic motors contained within a motor housing 63. One of the motors is provided for driving the upper track in a clockwise direction for retracting the advancing conduit, while the other motor is provided for driving the upper track in a counter-clockwise direction for advancing the advancing conduit. A similar pair of motors are housed within a motor housing 64 for driving the lower track 62.

A pair of guide rollers 66 and 67 are rotatably mounted between the parallel plates 52 and 53. Adjustment means indicated generally at 68 and 69 are provided for adjusting the positions of the guide rollers 66 and 67 relative to each other and relative to the upper and lower tracks 61 and 62. A second pair of guide rollers 71 and 72 are rotatably mounted between the parallel plates 52 and 53 in the vicinity of the head portion 58. Slots 73 and 74 are provided in the parallel plates 52 and 53 in the vicinity of the head portion 58. The position of the rollers 71 and 72 can be adjusted along the slots and therefore can be adjusted relative to the vertical position of rollers 66 and 67 and upper and lower tracks 61 and 62. With this construction, the rollers 71 and 72 can be adjusted to instill, maintain or eliminate a curvature in the advancing conduit 46 as it is advanced or retracted with the advancing and retracting mechanism 51.

Figs. 3A and 3B schematically show portions of the tunneling apparatus in use in tunneling under a roadway R. The takeup reel 36 and the advancing and retracting mechanism 51 of the tunneling apparatus 20 are positioned adjacent an access pit P previously dug in the ground by conventional techniques. At a forward or leading end indicated generally at 76 of advancing conduit 46 a coupling member 77 couples the advancing conduit 46 to a

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drill motor 78. A forward bent housing 79 is mounted to the drill motor at a 2° angle relative to the drill motor. While 2° has been found to be particularly effective, other angles might work satisfactorily. The coupling 77 and the drill motor 78 are coaxially aligned with a longitudinal axis of the advancing pipe 46. While the advancing pipe 46 has some flexibility, the straightened portion which is forced through the ground generally defines a longitudinal axis. A drill bit or drill member 81 is rotatably mounted to the bent housing 79 so that as the drill bit 81 rotates to define a drilling axis, the drilling axis is at a 2° angle relative to the longitudinal axis of the motor 78, the coupling 77 and the longitudinal axis of the advancing conduit 46.

15 A radio transmitter 82 is positioned near the leading end of the conduit and transmits signals which can be received by a receiver 83. Preferably, the receiver 83 is a directionally sensitive receiver which includes depth sensing capabilities.

20 As shown in Figs. 4 and 5, the coupling member 77 is tubular and is substantially the same diameter as the advancing conduit 46 and the drill motor 78. The coupling member 77 includes three distinct elements, namely a first portion 86, a collar 87 and a second portion 88. The first portion 86 is threadedly mounted to the advancing conduit 46 and includes a threaded shaft 90 and a toothed face 91. Second portion 88 is threadedly mounted to the drill motor 78 and includes a smooth shank 92, a flange 93 and a toothed face 94. The toothed face 94 is a complementary surface for engaging with the toothed face 91. A butt end 96 of the collar 87 is rotatably received about the smooth shank 92 of the second portion 88 of the coupling member and it is retained thereagainst by the flange 93. The collar 87 also includes a threaded end 97 for engagement 35 with the threaded shaft 90 of the first portion 86.

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The motor 78 is of a Moineau type and includes an outer casing 101, a stator 102 and a rotor 103. Preferably, the casing 101 is made of an alloy steel, the stator is made of a durable rubber compound and the rotor 5 is of a metal which has been hard chrome plated for durability. The rotor 103 is generally spiral and the stator 102 defines a corresponding spiral cavity 104 within which the rotor can rotate. The theory of operation of a motor of this type is that as fluid is forced through 10 the stator under pressure it causes the rotor to rotate.

As shown in Fig. 6A, the drill bit is rotatably mounted to a forward portion of the bent housing 79. It has been found that using a drill bit 81 which cuts a bigger diameter hole than the diameter of the conduit that 15 follows behind it provides sufficient clearance to allow effective steering of the tunneling apparatus; therefore, drill bit 81 is substantially larger in diameter than either bent housing 79 or the other cylindrical components (i.e. the drill motor and advancing conduit). In Fig. 6A, 20 drill bit 81 is seen to comprise a multi-toothed cutter including tungsten carbide inserts for durability. As shown in Fig. 6B, drill bit 81 can be replaced with other suitable drill bits, such as drill bit 111. Drill bit 111 is made up of a number of individual cutting surfaces 25 provided with man-made diamond material. Regardless of the particular drill bit used, it is important that the drill bit include a passageway therethrough such as the passageway 106 in drill bit 81 or the passageway 112 in drill bit 111. These passageways are important to allow 30 fluid which has been used to drive the drill motor 78 to pass out through the end of the drill bit.

OPERATION

In use, the tunneling apparatus 20 is towed to the site at which the tunneling is to be performed. A 35 small access pit P is dug to provide a starting place for

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the tunnel and to act as a collection pit for fluid and soil. With the tunneling apparatus 20 positioned adjacent the access pit P, the engine 31 is operated to provide hydraulic power by means of the hydraulic pump 32. The 5 leveling jacks 27 are then used to level and brace the tunneling apparatus upon the ground. Hydraulic jack 59 is then used to move the advancing and retracting mechanism 51 to a desired initial angle at which the advancing conduit 46 will enter the ground. After mounting the drill 10 motor and drill bit to the leading end of the advancing conduit, the advancing conduit, drill motor and drill bit are then ready to be inserted into the ground for tunneling.

For advancing or retracting the advancing conduit 15 46, hydraulic power is supplied to the hydraulic motors contained within the motor housings 63 and 64 to drive the upper and lower tracks 61 and 62, forcing the advancing conduit in either a forward or a rearward direction as desired.

20 To drive the drill bit 81, water is provided under pressure, as by pump 32 or other suitable means, through the advancing conduit. The water is pumped through the hub of the take-up reel 36, through the flexible conduit 48 and then through the advancing conduit 46. The 25 water is pumped under several hundred PSI pressure through the advancing conduit 46, through the coupling member 77 and through the drill motor 78. As the water flows through the stator cavity 104 and around the rotor 103, it causes the rotor to rotate within the stator. The rotary motion 30 of the rotor is transmitted by an unshown drive shaft within the bent housing 79 to the drill bit 81, thereby driving the drill bit. The fluid which has flowed through the drill motor 78 also flows through the bent housing 79 and ultimately through the end of the drill bit 81. The 35 water or fluid preferably contains additives, such as

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powdered clay, which facilitate the cutting action of the drill bit as it engages the soil or rock and stabilize the walls of the tunnel. As the drill bit rotates, its cutting teeth mechanically dig into the soil or rock to form the
5 tunnel. The loosened soil or rock is carried along with the water along the tunnel back toward the access pit P. In this regard, the drill bit 81 being of a larger diameter than the drill motor or the advancing conduit provides adequate clearance to facilitate the rearward
10 transport of the water and the soil or rock. Preferably, the water is retrieved from the access pit and recycled for further use.

As the drill bit, bent housing, drill motor and advancing conduit progress through the soil, it is
15 important to determine where the tunnel is being formed in order to make any necessary correction. As shown in Figs. 3A and 3B, a radio transmitter 82 can be implanted within the leading end of the advancing conduit and signals can be detected from the radio transmitter with an appropriate
20 receiver, such as receiver 83. Preferably, the receiver is directionally sensitive and is capable of determining the depth of the signal so that the operator can determine both the lateral and vertical position of the tunnel. Other alternative methods of sensing the position are of
25 course possible. For example, one can introduce a signal into the advancing conduit, drill motor and bent housing to use these components as an antenna. The signal created by this antenna can then be detected above ground. This has the advantage of allowing an operator to determine
30 where the end of the bent housing is located, which might be difficult when using a implanted radio transmitter. This is so because an implanted radio transmitter which is placed internally of one of the tubular elements must be hollow to allow fluid to pass therethrough or if it is
35 planted on the outside, must be securely planted so that

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it is not scraped off during tunneling. Other known position sensing techniques might be equally appropriate for use with the present invention, including gyroscopic techniques.

5 With the tunneling being performed and sensed as above, the apparatus can be steered as follows to urge the tunnel toward the desired path. The advancing conduit 46 is withdrawn from the tunnel, bringing with it the drill motor and bent housing. With the coupling member 77 pulled
10 out of the tunnel, the coupling member can be used to reorient the bent housing and the drill bit relative to the longitudinal axis of the advancing conduit. To reorient the drill motor 78 (and thereby the drill bit) relative to the advancing conduit 46, one unthreads the
15 collar 87 from the threaded shank 90 of the first portion 86 of the coupling 77. By this action, the mating toothed faces 91 and 94 are moved away from each other. With the toothed faces disengaged from each other, one rotates the drill motor relative to the advancing conduit 46 to
20 achieve the orientation desired. While holding the drill motor in this new orientation, one then rethreads the collar 87 onto the threaded shank 90 to engage the toothed faces 91 and 94 to lock the drill motor in the new orientation. In reorienting the drill motor 78 relative to
25 the advancing conduit 46, the advancing conduit 46 is incapable of significant rotation because the advancing conduit at the opposite end is wound upon the take-up reel. After the drill motor and drill bit have been reoriented relative to the longitudinal axis of the
30 advancing conduit, the advancing conduit and the drill and drill motor are reinserted into the tunnel and tunneling is commenced again along the new orientation. In most utility tunneling applications, the length to be traversed is several hundred feet or less and accordingly, this
35 withdrawal, reorientation and reinsertion technique has

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been found to be satisfactory.

There are some instances where no lateral steering would be required, for example, where one wanted to tunnel straight across and under a roadway without turning left or right as the tunneling progresses. In that event, it is possible to use the tunneling apparatus to create a tunnel without sensing the position of the equipment and without effecting any steering. This is accomplished by initially orienting the drill bit and drill motor so that the drill bit is pointing straight up at a 2° angle from the advancing conduit. The advancing conduit is then directed into the ground at an angle and as it is advanced through the ground, the 2° angle of the bent housing and drill bit slowly pull it back upwardly and cause the drill to surface a certain distance away. For example, in one particular application using a 2° bent housing, the tunneling was begun in an access pit at a level 42 inches below the surface of the ground. The advancing and retracting mechanism was adjusted so that the advancing conduit was oriented at a 4-1/2° angle below horizontal and tunneling commenced through the ground with the drill bit surfacing approximately 135 feet away from the access pit. In this type of tunneling, the entry angle is of course very important, as is the angle of the bent housing.

Those skilled in the art will recognize that in some circumstances it is desirable to tunnel substantially straight prior to or after a turn. In that event, it is possible to temporarily replace the bent housing with a straight housing (i.e., a housing mounted to the drill motor at a 0° angle) to tunnel in a straight, unsteered manner. On the other hand, one can form a relatively straight tunnel section by using the bent housing and judiciously reorienting the drilling to form a tunnel with a very slight zig-zag shape.

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While coupling member 77 is quite effective, it may be desirable in some circumstances to replace that coupling with a coupling that can be remotely manipulated without withdrawing the advancing pipe from the tunnel.

5 Such a remotely manipulated coupling can take the form of an electric or hydraulic motor which can be remotely controlled to turn the drill motor in fine increments relative to the advancing conduit. Of course, any such remotely manipulated motor should include a passage
10 therethrough for allowing fluid to be communicated to the drill motor. However, if an electric drill motor or some other type of drill motor is employed, the need for a fluid passage therethrough might be obviated.

While the invention has been described in a
15 preferred form, it will be readily apparent to those skilled in the art that many modifications, additions and deletions may be made therein without departing from the spirit and scope of the invention. For example, it is possible to mount a coupling member between the drill
20 motor and the bent housing rather than between the advancing conduit and the drill motor.

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We claim:

1. An apparatus for forming an underground tunnel for the reception of cable, pipes, and the like comprising
 - 5 a support frame,
 - an elongated, substantially continuous conduit having a leading end, said conduit having a longitudinal axis,
 - a reel mounted to said support frame for
10 receiving said conduit,
 - a drill motor mounted to said leading end of said conduit,
 - a drill member coupled to said drill motor at an angle relative to the longitudinal axis and oriented
15 relative to said conduit to define a first drilling direction,
 - means for changing the orientation of said drill member relative to the longitudinal axis of said conduit without rotating said conduit to define a second drilling
20 direction,
 - means for powering said drill motor to cause rotation of said drill member, and
 - means for advancing the conduit along the tunnel.
2. An apparatus as claimed in claim 1 wherein
25 said drill motor is a hydraulic motor.
3. An apparatus as claimed in claim 2 wherein said means for powering said drill motor comprises means for supplying a supply of fluid under pressure to said drill motor.
- 30 4. An apparatus as claimed in claim 2 wherein said drill motor comprises an elongated rotor, an elongated stator and a tubular casing having a longitudinal axis.

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5. An apparatus as claimed in claim 4 wherein said longitudinal axis of said tubular casing is substantially parallel to said longitudinal axis of said elongated conduit.

5 6. An apparatus as claimed in claim 5 further comprising a tubular member having a longitudinal axis, said tubular member being mounted between said drill motor and said drill member, said longitudinal axis of said tubular member being positioned at an angle relative to
10 said longitudinal axis of said elongated conduit.

7. An apparatus as claimed in claim 1 wherein said means for changing the orientation of said drill member comprises a tubular coupling member comprising a first portion adapted to be mounted to said elongated
15 conduit and a second portion adapted to be positioned at a plurality of angular positions with respect to said first portion.

8. An apparatus as claimed in claim 1 further comprising wheels rotatably mounted to said support frame.

20 9. An apparatus as claimed in claim 1 wherein said drill member is coupled to said drill motor at a fixed angle relative to the longitudinal axis and wherein said means for changing the orientation of said drill member is adapted to do so while maintaining said drill
25 member at said fixed angle.

10. An apparatus for forming an underground tunnel such as for the reception of utility cable, conduits and the like along a desired path, the apparatus comprising:

- 5 a support frame;
- a length of semi-rigid advancing conduit;
- a reel rotatably mounted to said support frame for receiving said advancing conduit;
- means for wrapping said advancing conduit about
- 10 said reel and for unwrapping said advancing conduit from said reel, for substantially straightening said advancing conduit as it is unwrapped and for urging the straightened advancing conduit in a forward direction;
- a tubular coupling member having a longitudinal
- 15 axis and comprising a first portion adapted to be mounted to said advancing conduit and a second portion adapted to be positioned at a plurality of angular positions with respect to said first portion without rotating said first portion relative to said advancing conduit; and
- 20 a drill mounted to said second portion of said coupling member for rotation about a drilling axis oriented at an angle relative to said longitudinal axis of said coupling member.

11. An apparatus as claimed in claim 10 further

25 comprising an hydraulic drill motor mounted between said advancing conduit and said drill for driving said drill.

12. An apparatus as claimed in claim 11 further comprising means for providing a supply of fluid under pressure for powering said hydraulic drill motor.

30 13. An apparatus as claimed in claim 11 wherein said hydraulic motor comprises a tubular casing having a longitudinal axis, an elongated stator and an elongated rotor.

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14. An apparatus as claimed in claim 13 wherein said longitudinal axis of said hydraulic motor is substantially parallel to said longitudinal axis of said coupling member.

5 15. In a utility tunneling apparatus of the type having a coil of semi-rigid advancing pipe for tunneling substantially horizontally underground for the installation of cables, conduits and the like, the improvement therein comprising:

10 a tubular coupling member having a longitudinal axis and comprising a first portion adapted to be mounted to the advancing pipe and a second portion adapted to be positioned at a plurality of angular positions with respect to the first portion; and

15 a drill mounted to said coupling member second portion for rotation about a drilling axis oriented at an angle with respect to said longitudinal axis of said coupling member.

16. A method of forming an underground tunnel
20 for the reception of cables, pipes and the like using a tunneling apparatus of the type having a length of semi-rigid advancing conduit mounted about a reel, the advancing conduit having a longitudinal axis and a fluid powered drill motor coupled to the leading end thereof for
25 driving a rotatable drill bit, wherein the drill bit is positioned at an angle to the longitudinal axis and oriented relative to the conduit to define a first drilling direction, the method comprising the steps of supplying fluid under pressure through the conduit for
30 powering the drill motor, monitoring the direction of the tunneling, and changing the orientation of the drill bit relative to the advancing conduit without rotating the advancing conduit when a new drilling direction is desired.

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17. The method as claimed in claim 16 further comprising the steps of:

withdrawing the advancing conduit, drill motor and drill bit from the tunnel prior to the step of
5 changing the orientation of the drill bit; and

replacing the advancing conduit, drill motor and drill bit in the tunnel after the step of changing the orientation of the drill bit.

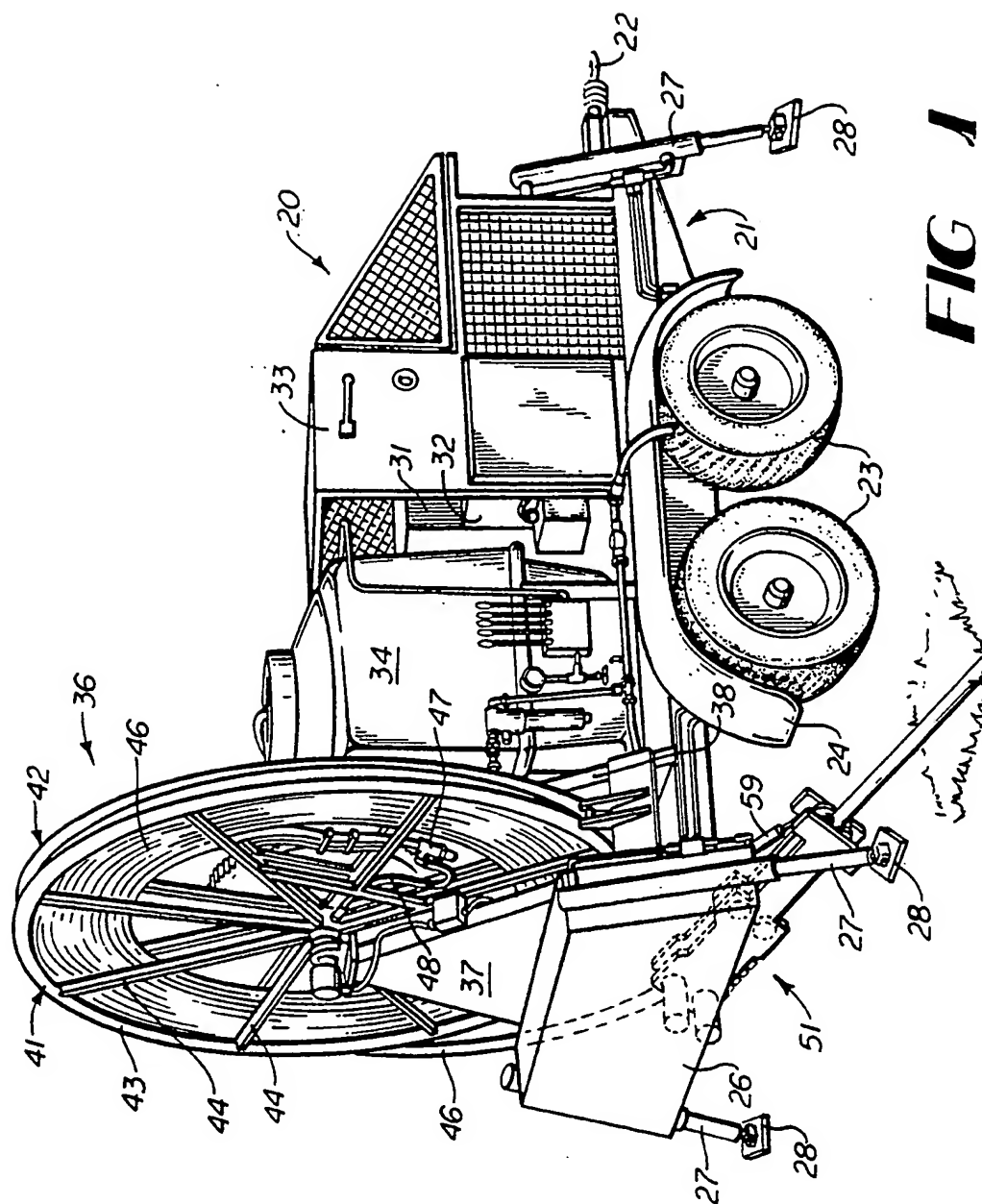
18. A method of tunneling substantially
10 horizontally underground such as for the installation of utility pipes, cables and the like along a desired path using a tunneling apparatus having a length of advancing conduit received upon a reel, the advancing conduit having a longitudinal axis and being coupled at one end to a
15 drill motor for driving a drill, the drill being oriented in a first direction at an angle relative to the longitudinal axis of the advancing conduit, comprising the steps of: moving the advancing conduit in a forward direction;

20 monitoring the progress of the tunneling relative to the desired path; and

periodically changing the orientation of the drill relative to the longitudinal axis of the advancing conduit without rotating the advancing conduit.

25 19. The method as claimed in claim 18 wherein the drill motor is fluid powered and further comprising the step of supplying fluid under pressure for powering the drill motor to drive the drill.

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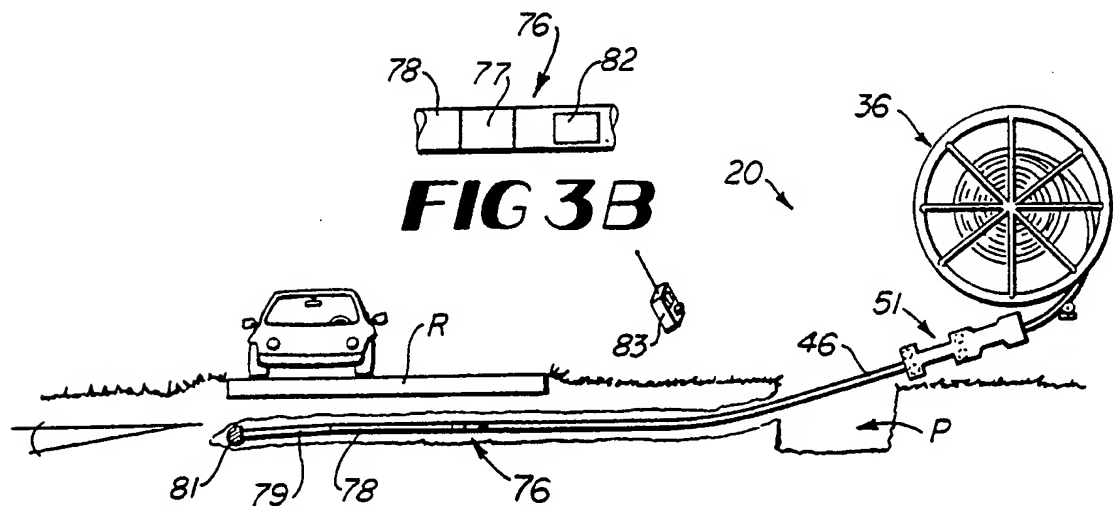
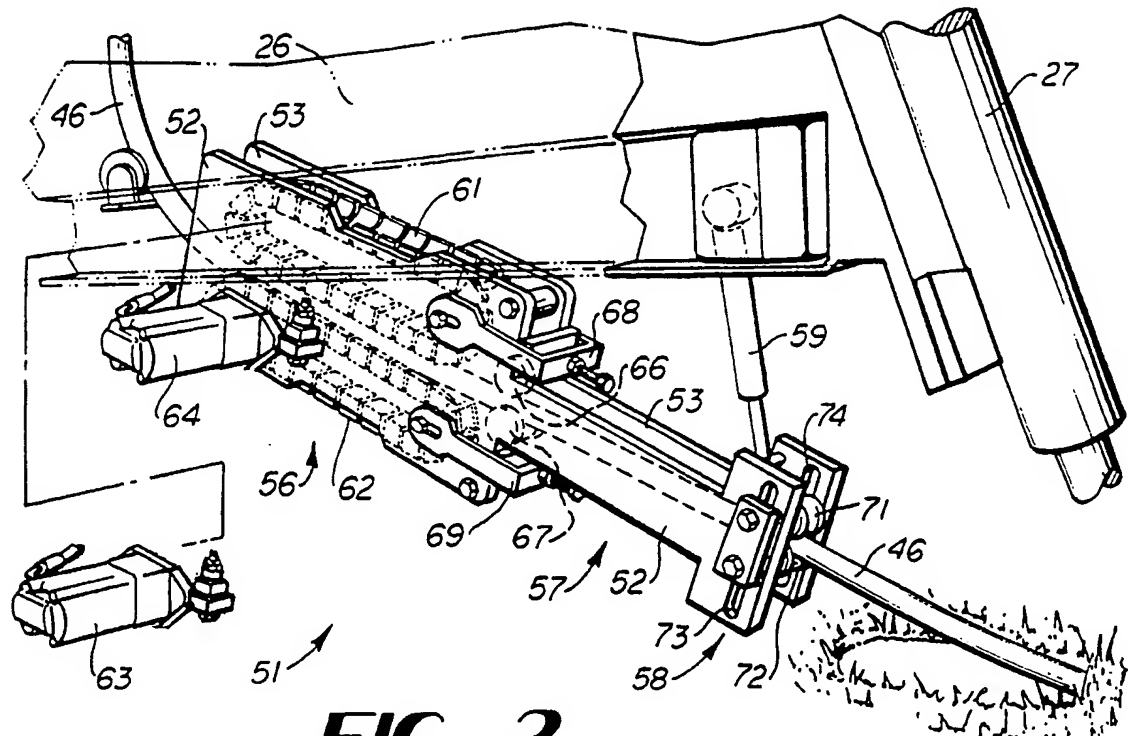


FIG 3A

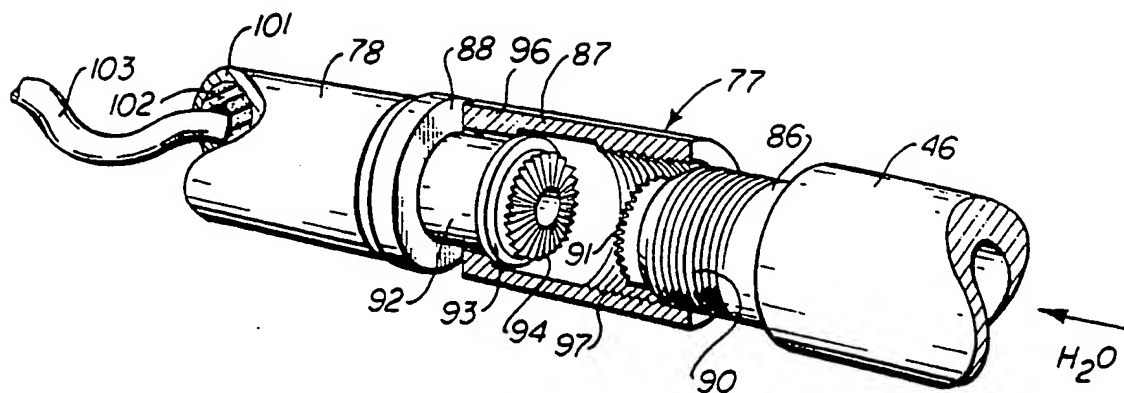


FIG 4

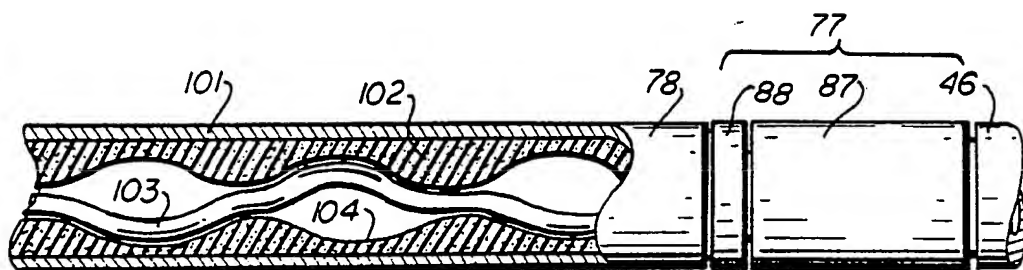


FIG 5

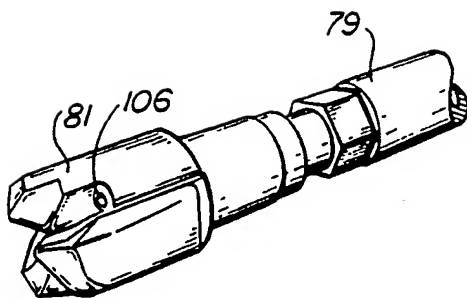


FIG 6A

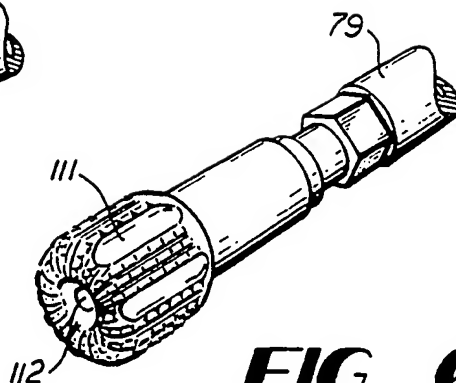
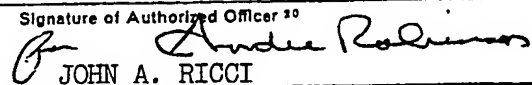


FIG 6B

INTERNATIONAL SEARCH REPORT

International Application No. **PCT/US91/00469**

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) ³		
According to International Patent Classification (IPC) or to both National Classification and IPC IPC (5): F16L 1/028; E21B 7/08 U.S. Cl: 405/184, DIG.12; 175/61,62		
II. FIELDS SEARCHED		
Minimum Documentation Searched ⁴		
Classification System	Classification Symbols	
U.S.	405/184, DIG.12 ; 166/77, 384; 175/61, 62, 75	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁵		
III. DOCUMENTS CONSIDERED TO BE RELEVANT ¹⁴		
Category ⁶	Citation of Document, ¹⁶ with indication, where appropriate, of the relevant passages ¹⁷	Relevant to Claim No. ¹⁸
A	US, A, 4,026,371 (TAKADA et al) 31 May 1977 See column 7, line 38 to column 8, line 21	1-7, 11-14
Y	US, A, 4,067,404 (CRASE) 10 January 1978 See column 3, lines 23-66.	1-3,7,9-12, 15-19
A	US, A, 4,396,073 (REICHMAN et al) 02 August 1983 See column 6, line 48 to column 7, line 2.	1, 7, 9
A	US, A, 4,433,738 (MORELAND) 28 February 1984 See column 4, lines 13-37.	1-7, 9
A	US, A, 4,542,647 (MOLNAR) 24 September 1985 See column 1, line 50 to column 2, line 24.	1, 10
A	US, A, 4,655,299 (SCHOEFFLER) 07 April 1987 See column line 20 to column 2, line 10.	1-3,7,9-12, 15-19
A	US, A, 4,787,463 (GELLER et al) 29 November 1988 See column 1, lines 40-64.	1-3,7,9-12, 15-19
A	US, A, 4,813,497 (WENZEL) 21 March 1989 See column 2, lines 4-39.	1,7,9,10,17
<div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p>¹⁵ Special categories of cited documents:</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> </div> <div style="width: 45%;"> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"A" document member of the same patent family</p> </div> </div>		
IV. CERTIFICATION		
Date of the Actual Completion of the International Search ¹		Date of Mailing of this International Search Report ²
20 MARCH 1991		29 APR 1991
International Searching Authority ¹		Signature of Authorized Officer ¹⁰
ISA/US		 JOHN A. RICCI

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

Y	US, A, 4,856,600 (BAKER et al) 15 August 1989 See column 3, line 37 to column 6, line 47.	1-3,7-12, 15-19
A	US, A, 4,867,255 (BAKER et al) 19 September 1989 See column 1, line 58 to column 2, line 30.	1,10,15-19
Y,P	US, A, 4,936,397 (MCDONALD et al) 26 June 1990 See column 7, line 15 to column 8, line 48.	4,5,6,13,14
A	"Datadril MWD System" brochure, Smith International, updated	1-3,10,15-19
A	Frank Ruffer, "Drehteile and Dusen fabrikation" brochure, updated	1,10,15,16,18

V. ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE¹

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☐ Claim numbers because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claim numbers because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out¹, specifically:

3. ☐ Claim numbers because they are dependent claims not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI. ☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING²

This International Searching Authority found multiple inventions in this international application as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category *	Citation of Document, ¹⁶ with indication, where appropriate, of the relevant passages ¹⁷	Relevant to Claim No ¹⁸
A	Mechanique Populaire, July 1955 Page 89	1,10,15,16,18
A	Slimdril International, Horizontal Drilling, High performance drill bits brochure, updated	1-3,10,15-19
A	Downhole Engineering Inc. brochure, "My-D-MO" updated	1-3,10,15-19
A	Flow Mole Corporation brochure, "Guide Drill" updated	1-3,10,15-19
A	US,A, 3,455,401 (TAYLOR) 15 July 1969 see column 10, line 61 to column 11, line 61.	1-6,11-14
A,P	US,A 4,905,774 (WITTRISCH) 06 March 1990 see the abstract	1,10
A	"MIT Cail Drill-200" Brochure, Trenchless Technology and Construction, Inc. Undated	1,8,10 15-19

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